Comparison of Calpuff Results With and Without ENSR RUC/MM5 Data for Year 2000

June 2003

North Dakota Department of Health
Division of Air Quality
1200 Missouri Avenue
Bismarck, ND 58506

Introduction

Much discussion has recently been focused on the use of mesoscale meteorological data, such as MM5, in Calpuff PSD Class I increment modeling for North Dakota. Basin Electric, through its consultant ENSR, has provided an MM5 data set for Year 2000. The data set is consistent with the regional modeling domain used by the North Dakota Department of Health (NDDH) for PSD Class I increment studies, and was developed using output from the RUC2 forecast model used by the National Weather Service (NWS). This report provides a straightforward "apples-to-apples" comparison of Calpuff modeling results for Year 2000 obtained with and without use of the ENSR RUC/MM5 data.

The Calpuff modeling system includes the meteorological preprocessing program Calmet. In its default mode, Calmet is executed using NWS observations (i.e., twice daily upper-air and hourly surface), only. Optionally, Calmet can be executed using mesoscale meteorological model wind fields, such as produced by MM5, to supplement the NWS observations.

Prior to receiving the ENSR RUC/MM5 data, the NDDH had executed Calmet with NWS observations only in its PSD Class I analysis for Year 2000 (however, the NDDH had incorporated MM data in its modeling for Years 1990 and 1992). Upon receiving the ENSR data for Year 2000, the NDDH examined the effect on Calpuff predictions after the addition of the RUC/MM5 data (unmodified) in Calmet processing.

A comparison of Calpuff results with and without inclusion of the RUC/MM5 data was effected for three scenarios:

1. PSD Class I increment modeling using the State's methodology and inputs, including the State's emission inventory (May 2003)[1],

2. PSD Class I increment modeling using EPA's methodology and inputs, including the EPA emission inventory (May 2003)[2] with the exception of the Dakota Gasification Company's Synfuels

---

[1] NDDH, 2003. Calpuff Analysis of Current PSD Class I Increment Consumption in North Dakota and Eastern Montana Using Actual Annual Average SO_2 Emission Rates. North Dakota Department of Health, Bismarck, North Dakota 58506.

[2] EPA, 2003. Dispersion Modeling Analysis of PSD Class I Increment Consumption in North Dakota and Eastern Montana. United States Environmental Protection Agency Region 8, Denver, Colorado 80202.

Plant (DGC) and the Little Knife Gas Processing Plant (Little Knife), and

3. Calpuff performance evaluation using actual hourly emission rates for Year 2000.

Comparisons were based on the 24-hour averaging period, as that period has proven to be the most constraining in regulatory PSD Class I analyses. For each scenario comparison, all modeling inputs were identical except for the meteorological data used to drive the Calpuff model, thus providing true "apples-to-apples" comparisons to isolate the effect of the meteorological data.

Comparison Based on North Dakota Methodology/Inputs

The comparison of Calpuff results, with and without ENSR RUC/MM5 data, for the NDDH PSD Class I modeling scenario is summarized in Table 1. The baseline concentration determined as the second-high (receptor averaged) concentration from baseline-period source emissions and the second-high (receptor averaged) concentration determined from current-period source emissions are shown for each North Dakota PSD Class I area. (Since one exceedance of the PSD Class I increment is allowed by law, the second-high concentration determined from current-period source emissions is shown.) The difference reflects the deterioration (increase) or improvement (decrease) in the second-high concentration.

The MAAL equals the sum of the baseline concentration and the PSD increment (i.e., 5 $\mu g/m^3$ for 24-hour). The "Buffer" entry is the difference between the MAAL and the second-high current-period prediction. Values of Buffer less than zero indicate that the increment has been consumed and values greater than five indicate that the predicted second-high concentration has decreased. All values for Buffer in Table 1 are greater than zero.

Though the model predictions for both baseline and current periods generally decrease when using RUC/MM5 data, Table 1 indicates that only one of the four PSD Class I areas has a larger Buffer when using RUC/MM5 data and, thus, a greater margin for future deterioration before an increment exceedance would occur.

Comparison Based on EPA Methodology/Inputs

The comparison of Calpuff results, with and without ENSR RUC/MM5 data, for the EPA PSD Class I modeling scenario is summarized in Table 2. The high, second-high (no receptor averaging) prediction is provided for each North Dakota Class I area. Because the EPA source inventory includes increment-affecting emission rates only, the Table 2 predictions are directly comparable with the Class I increment (5 $\mu g/m^3$). Note that the emission inventory used for this comparison did not include the variance sources modeled by EPA (i.e., DGC and Little Knife). Also, the emission inventory included the May 2003 version of the NDDH minor-source oil and gas inventory (EPA used the April 2002 version).

As shown in Table 2, predictions obtained with RUC/MM5 data are generally lower than those without. For the worst-case location (TRNP South Unit), the prediction obtained using RUC/MM5 data (6.7 Fg/m^3) is 25 percent lower than the prediction without RUC/MM5 (8.5 Fg/m^3).

<u>Comparison of Performance Evaluations</u>

Calpuff performance evaluations were conducted for Year 2000 with and without the RUC/MM5 data, and are compared in Tables 3 and 4. Methodology and inputs for the performance evaluations are consistent with those previously used by the NDDH and described in "Evaluation of Calpuff Model Performance Using Year 2000 Data"[3]. To prepare the predicted-to-observed ratio averages reported in Table 3, the 24-hour block predictions and monitor observations at Dunn Center and TRNP South Unit (Year 2000) were ranked high to low. The fifty highest predictions were then paired with the fifty highest observations, and the ratio predicted-to-observed was calculated for each pair. The average of these 50 ratios is reported in Table 3 (i.e., values less than 1.0 imply an under prediction bias and values greater than 1.0 imply an over prediction bias). The use of the fifty highest values in Table 3 is consistent with the default output of the Calpuff system ("Max 50" table).

In its "Protocol for Determining the Best Performing Model,"[4] EPA suggests use of the highest 25 predictions and observations in statistics to assess model performance. Therefore, the average predicted-to-observed ratios in Table 4 were developed using the same approach as for Table 3, but with the highest 25 predictions and observations.

One associated issue of recent discussion is the appropriate magnitude of background concentration for the performance evaluation. The background concentration represents the impact of natural sources and distant/unmodeled sources and is added to the model predictions before making comparisons with observations.

---

[3] NDDH, 2003. Evaluation of Calpuff Model Performance Using Year 2000 Data. North Dakota Department of Health, Bismarck, North Dakota 58506.

[4] EPA, 1992. Protocol for Determining the Best Performing Model. Publication No. EPA-454/R-92-025, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711.

Unfortunately, this background is very small, and the sensitivity of current ambient SO_2 monitors located in Western North Dakota is insufficient to resolve it with certainty. A background value of 0.5 Fg/m^3 has been suggested by EPA[2], while a value of 2.0 Fg/m^3 has been assumed by ENSR[5]. A review by NDDH of TRNP South Unit monitoring data[3] (using raw un-rounded values filtered to eliminate hours with impact from modeled sources) suggests that the actual background falls somewhere near a range of 0.5 to 1.0 Fg/m^3; but again, limitations in instrument sensitivity do not permit derivation of a specific background value.

To address background value uncertainty, performance evaluation results in Tables 3 and 4 are presented for three different background assumptions, ranging from 0.0 to 1.0 Fg/m^3. As shown in the tables, the assumption regarding background value has an effect on potential conclusions regarding model performance. With a background near zero, a small under prediction bias is associated with the RUC/MM5 data. With a background of 1.0 Fg/m^3, a small over prediction bias is found without RUC/MM5 data.

In summary, the results in Tables 3 and 4 suggest Calpuff performs well with or without inclusion of the ENSR RUC/MM5 data, and it performs modestly better with ENSR RUC/MM5 at TRNP South Unit, notwithstanding uncertainty regarding background concentration. Regardless of selected background, the predicted/observed ratio is well within the factor-of-two recommended by EPA.

<u>Comparison Limitations</u>

Tables 1 and 2 also illustrate differences in outcome of NDDH and EPA modeling protocols related to status of deterioration of sulfur dioxide and consumption of PSD increments in North Dakota PSD Class I areas. The scope of this document does not examine reasons for these differences, such as use of baseline concentration as the benchmark for deterioration or improvement in ambient sulfur dioxide and sulfur dioxide emission rate inputs.[6]

---

[5] ENSR, 2003. Revised Calpuff Analysis with Year 2000 MM5 Meteorological Data: PSD Increment Consumption in Class I areas in North Dakota and Eastern Montana. ENSR Corporation Document Number 3496-010-100.

[6] NDDH, 2003. A Comparison of State and EPA Sulfur Dioxide Emission Rates Used in Recent Air Quality Modeling. North Dakota Department of Health, Bismarck, North Dakota 58506.

Table 1

Comparison of Calpuff 24-hr SO_2 Results With and Without
ENSR RUC/MM5 Data for Year 2000 - PSD Class I
Increment Modeling Using NDDH Methodology and Inputs
(Fg/m^3)

	TRNP South	**TRNP North**	**TRNP Elkhorn**	**Lostwood NWA**
With RUC/MM5				
Baseline concentration	6.3	29.7	21.0	6.5
2nd High current period	8.8	9.9	13.1	7.7
Difference *	2.5	(19.8)	(7.9)	1.2
- - - - - - - - - - - - - - - - -	- - - - -	- - - - -	- - - - -	- - - - -
Baseline concentration + 5 (MAAL)	11.3	34.7	26.0	11.5
Buffer (MAAL - 2nd High current) **	2.5	24.8	12.9	3.8
Without RUC/MM5				
Baseline concentration	10.4	25.2	25.3	13.2
2nd High current period	12.9	10.2	16.5	12.3
Difference *	2.5	(15.0)	(8.8)	(0.9)
- - - - - - - - - - - - - - - - -	- - - - -	- - - - -	- - - - -	- - - - -
Baseline concentration + 5 (MAAL)	15.4	30.2	30.3	18.2
Buffer (MAAL - 2nd High current) **	2.5	20.0	13.8	5.9
Comparison of "buffer" with RUC/MM5 to "buffer" without RUC/MM5	same	larger	smaller	smaller

* Numbers are deterioration or improvements (decreases) in second-high concentrations.
** The buffer also is equal to 5 minus the "difference."

Table 2

Comparison of Calpuff 24-hr SO_2 Results With and Without
ENSR RUC/MM5 Data for Year 2000 - PSD Class I
Increment Modeling Using EPA Methodology and Inputs*
(Fg/m^3)

	TRNP South	**TRNP North**	**TRNP Elkhorn**	**Lostwood NWA**
With RUC/MM5 High, 2nd High Prediction**	6.7	5.3	1.7	4.6
Without RUC/MM5 High, 2nd High Prediction**	8.9	5.4	4.4	6.6

* Except that the emission inventory used here did not include the variance sources modeled by EPA (i.e., Dakota Gasification Company's Synfuels Plant and Little Knife Gas Processing Plant).

** Because the EPA source inventory includes increment-affecting emission rates only, the predictions are directly comparable with the PSD Class I increment of 5 Fg/m^3.

Table 3

Comparison of Calpuff Performance Evaluation
Results With and Without ENSR RUC/MM5 Data
for Year 2000 - Ratio of Calpuff Predicted
to Observed (Average for 50 highest 24-hr predictions
and observations)

Background = 0

	Dunn Center	**TRNP South**
With RUC/MM5	0.82	0.77
Without RUC/MM5	0.97	1.00

Background = 0.5 Fg/m^3

	Dunn Center	**TRNP South**
With RUC/MM5	0.90	0.89
Without RUC/MM5	1.05	1.12

Background = 1.0 Fg/m^3

	Dunn Center	**TRNP South**
With RUC/MM5	0.98	1.00
Without RUC/MM5	1.13	1.24

Table 4

Comparison of Calpuff Performance Evaluation
Results With and Without ENSR RUC/MM5 Data
for Year 2000 - Ratio of Calpuff Predicted
to Observed (Average for 25 highest 24-hr predictions
and observations)

Background = 0

	Dunn Center	**TRNP South**
With RUC/MM5	0.90	0.92
Without RUC/MM5	1.07	1.20

Background - 0.5 Fg/m^3

	Dunn Center	**TRNP South**
With RUC/MM5	0.96	1.02
Without RUC/MM5	1.13	1.29

Background = 1.0 Fg/m^3

	Dunn Center	**TRNP South**
With RUC/MM5	1.03	1.12
Without RUC/MM5	1.19	1.39